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SINTERING OF CERMET PRODUCTS COMPRESSED BY IMPACT LOADS

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Discussion of the physical and mechanical properties of cermet products obtained by sintering powdered iron at temperatures up to 1100°C under dynamic impact compression. Sintered iron compacts produced under impact compression are found to have higher work-hardening properties than products compressed statically. The experimental technique is described.

The effect which imperfections in the crystal structure have on the sintering process is discussed in several papers (refs. 1-8). It is experimentally shown by the authors of these works that the sintering rate increases considerably in specimens with defects in the crystal lattice which may develop during preliminary deformation or may be associated with nonequilibrium conditions in production of the powders. It is pointed out in reference 4, for instance, that specimens "...nearly free of distortions in the crystal lattice" had different initial shrinkage rates after cold working by compressive deformation (by 18, 20 and 50%) in a press. The shrinkage rate for specimens with a high degree of work-hardening was considerably higher than that of undeformed specimens or those deformed to a lesser degree. /6*

On the other hand, it may be concluded from work in the field of using explosive energy in powder metallurgy (refs. 9 and 10), metal hardening (ref. 11) etc., that high rates of load application alter the physical characteristics of metals. Data are given in references 11 and 12 to the effect that iron is work-hardened to a higher degree by impact loading than by static loading even though the degree of deformation was considerably higher in the latter case.

On the basis of the above discussion it may be assumed that sintering of cermet products compressed by impact loads should be more rapid than that of "conventional" pressed products.

Experiments were done on specimens made from iron powder, grade PZhZM GOST (Government Standard) 9849-61, produced by reduction. The shape selected for the specimen (figure 1) makes it possible to measure the dimensions during sintering both in the direction of pressing as well as perpendicular to it. Powder grade identity, granulometric composition, oxygen and carbon concentration, lubrication of the press mold, holding time between pressing and sintering, and the density of the compressed specimens were rigidly controlled to eliminate the effect of various factors during comparison of the sintering processes for "static" and "dynamic" specimens. Analogy was maintained between the first three parameters

*Numbers given in margin indicate pagination in original foreign text.

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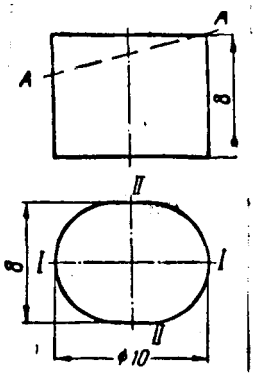

Figure 1. Specimen which was studied. A-A--plane in which microhardness was measured, I-I and II-II--directions in which microhardness was measured in plane A-A.

screening the -0068+0050 fraction from 1 batch and container. Table 1 shows the concentration of oxygen and carbon in the powder according to data of chemical analysis made by the Laboratory of Powder Metallurgy. The die cavity was lubricated /7 with a solution of zinc stearate in acetone. Holding time between pressing and sintering was no more than 15 minutes. The density of the pressed specimens (87%) was held constant within limits of ±10.5% by pressing a batch of a definite weight to the necessary dimension with respect to height (8mm). In addition, density was checked by hydrostatic weighing. "Static" pressing was done on a universal testing machine at a load application rate of 60 mm/min, while "dynamic" pressing was done on an explosive-driven hammer at the load application rate of 110-180 m/sec.

As a rule, the sintering process is accompanied by a change in the dimensions of the specimen, and in many cases observations of the behavior of this variation may be used to evaluate the sintering capacity of various compressed specimens. Different types of dilatometers are widely used for this purpose in powder metallurgy practice. In our work we used the conventional DKM optical dilatometer with a maximum magnification of 400.

The specimens were sintered in a special quartz system of our own design. The installation may be used to sinter specimens of practically any dimensions, and also permits delivery of the shielding atmosphere to the zone of the specimen and location of the thermocouple directly on its surface. In our experiments we used a neutral atmosphere, chemically pure argon, grade A (GOST 10157-62), after additional drying and purification from oxygen. The heating rate was 3 deg/min monitored by electronic instruments on the dilatometer. The specimen was put under a pressure of 0.8 daN/cm^2 by the weight of a quartz bar and the force of a compression spring. A graph of the variation in the dimensions of the specimen as a function of holding and heating time was automatically recorded on photographic paper by a tape transport mechanism in the dilatometer. The maximum heating temperature was 1100°C.

Figure 2 shows a graph for the change in size of a specimen pressed from PZhZM powder in the "as received" state as a function of temperature, and a second graph is given in figure 3 for a specimen completely reduced in an atmosphere of dissociated ammonia at a temperature of 780°C and annealed in an argon atmosphere under similar conditions. The reduction and annealing were done to determine the effect of the state of oxidation and initial "biographic" imperfection of the powder. The oxygen concentration and microhardness of the powders are given in table 1.

In addition, the microhardness was measured on the "dynamic" and "static" specimens. The following measurement method was used. Microsections on the specimens were prepared simultaneously on a single unit at an angle of 5 degrees to the upper end surface, as shown by the broken line in figure 1. The measurements were made every 0.15 mm along perpendicular diagonals. Each microsection underwent 100 measurements.

TABLE 1.

PZhZM powder	O_2,%	C,%	Microhardness daN/mm^2
as received	1.72	0.2	148--152
completely reduced	0.74	0.12	78--81
annealed	1.55	0.10	125--134

TABLE 2.

PZhZM powder	pressing method	Microhardness daN/mm^2
incomplete reduction	static	179--186
	dynamic	160--163
complete reduction	static	140--145
	dynamic	158--162

/8

Average values of microhardness for 100 measurements are given in table 2 for specimens made from partially and completely reduced powders pressed on a breaking test machine and by an explosive-driven hammer.

As may be seen from figures 2 and 3, the shrinkage-onset temperature and its values for "dynamic" specimens made from powder in the "as received" state are higher than those of the "static" specimens, while the shrinkage-onset temperatures for specimens made from annealed and completely reduced powders coincide, and their values for "dynamic" specimens are higher. The variation in microhardness shows similar behavior.

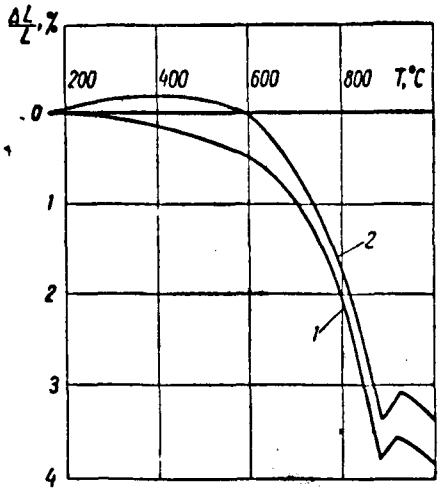

Figure 2. Variation in dimensions of specimens made from PZhZM powder in the delivered state pressed on a testing machine (1) and on the explosive-driven unit (2) as a function of temperature.

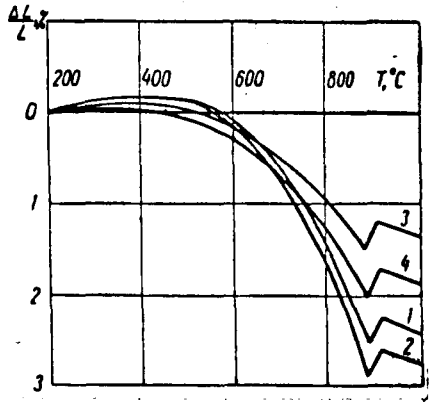

Figure 3. Variation in the dimensions of specimens made from PZhZM powders reduced (3,4) and annealed (2,1), pressed on the testing machine (1,3) and on the explosive-driven unit (2,4) as a function of temperature.

Analysis of the results indicates that the difference in behavior of "dynamic" specimens made from powder in the "as received" state as compared with specimens made from heat-treated powders is due to energy release. The pressing properties of annealed powders are considerably higher; consequently a projectile of identical weight must be moved more rapidly in pressing partially reduced

powders to give briquettes of the same density (87%). An increase in the pressing speed raises the briquette temperature, which is localized in the contact sections at the moment of pressing and thus to a considerable degree relieves residual stresses and reduces work-hardening of the contact surfaces. This also has an effect on reducing the activity in sintering "dynamic" specimens made from partially reduced powders.

When heat treated powders are pressed to the given density, the temperature does not reach the recrystallization point (the microhardness of "dynamic" specimens is higher), while the initial defects which cause shrinkage at low temperatures are annihilated during reduction or annealing. The slight increase in size in the 200-600°C range may be explained by expansion of the air in closed pores, which should amount in our case to 4-5% according to the data given in reference 13. In addition, it may be seen from figure 3 that the state of oxida- /9
tion of the powder has an identical effect on the sintering process in specimens produced at various rates. Oxides promoted shrinkage in both cases, although the effect of this factor is somewhat less for dynamically pressed specimens.

It is easily seen from a comparison of the final shrinkage values for partially reduced, annealed and completely reduced powders (figs. 2 and 3) that the difference in shrinkage of specimens pressed from partially reduced and annealed powders on the breaking test machine is 1.3% and that for similar specimens pressed on the explosive-driven hammer is 0.5%, while the difference for specimens made from annealed and completely reduced powders is equal to 1 and 0.75% respectively. When "static" briquettes were sintered from partially reduced powder, their shrinkage in comparison with that of briquettes made from annealed powder increased more from the effect of work-hardening (which is relieved while the specimen is still in the die during explosive pressing) than from the oxide film. Under the effect of other factors, it should be possible to observe a similar difference in the shrinkage of "dynamic" and "static" specimens made from annealed and partially reduced powders.

It has not been our purpose in this work to establish the nature of imperfections in the crystal lattice. However, it may be assumed from the nature of their effect on the sintering process and from data given in reference 5 that imperfections which develop to a greater degree during high-speed pressing than during static pressing are packing deformation defects.

Conclusions

1. Impact pressing has a considerable effect on the physical and mechanical characteristics of the material of cermet specimens.

2. Iron powders pressed on an explosive-driven unit to a density of 87% have higher work-hardening properties than those pressed by static loads.

3. The shrinkage rate of specimens made from iron powder in the α-phase pressed by dynamic loads is higher than that of specimens pressed by static loads.

4. The increase in activity of dynamic specimens during sintering may be explained by the increase in work-hardening during high-speed loading.

5. A further increase in pressing rates (in our case above 250 m/sec) results in simultaneous reduction in work-hardening due to the effect of energy release.

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